Global Water Budget Estimates and Uncertainties

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Workshop on
Satellite Observations of the Global Water Cycle
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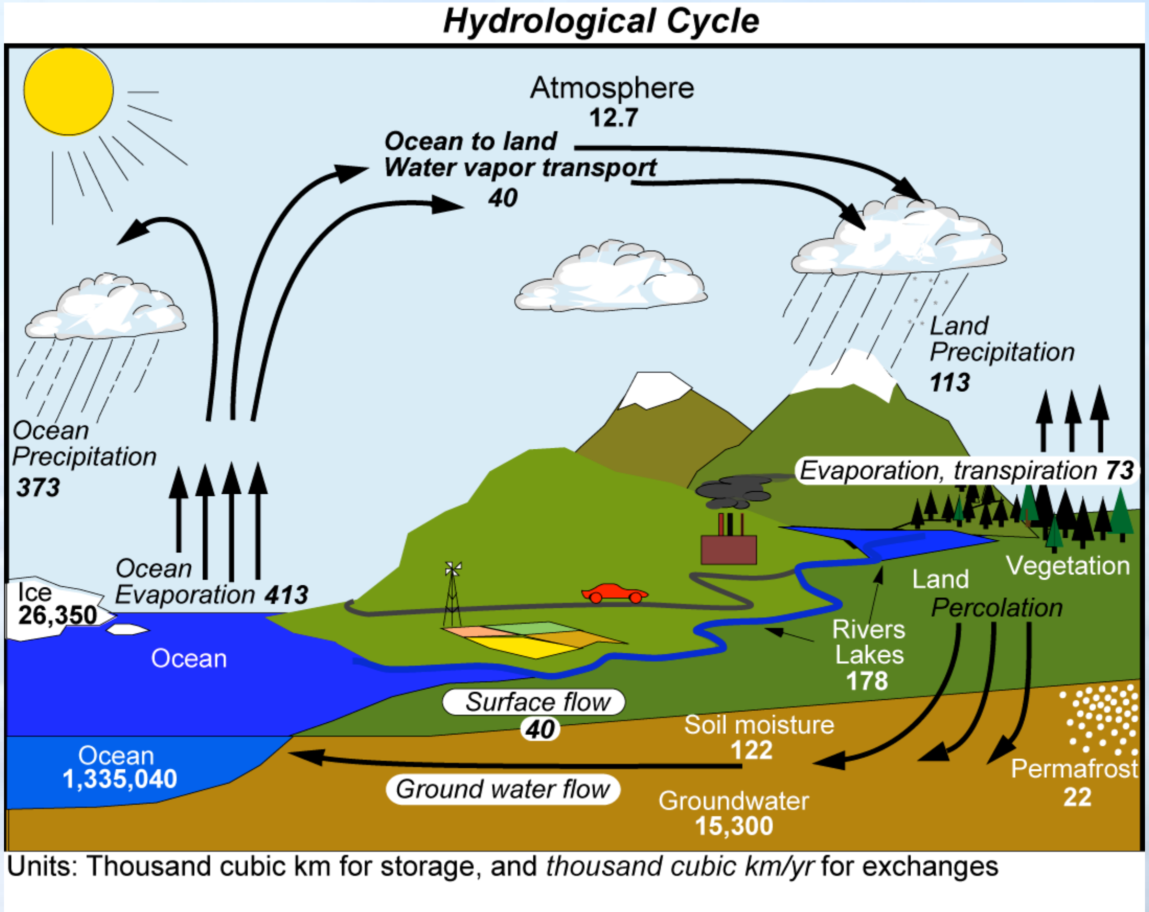
Global Hydrological cycle:

1. Mean
2. Annual cycle
3. Trends

Can we do this for each month of the year?

For each region?

Can we do time series?



Global hydrological cycle

Many previous estimates have been published, most without documentation of where the numbers come from. Many not independent (cascade of sources).

Dozier 1992

Chahine 1992

Schlesinger 1997

Peixoto & Oort 1992

Alley et al 2002

Shiklomanov 1997

Shiklomanov and Rodda (2003) is update.

Oki 1999

Oki and Kanae 2006

Gleick 1993:

“**Good water data are hard to come by**” **and data are** “**collected by individuals with differing skills, goals and intents**”

Shiklomanov (1993) in same volume collected definitive data of water reserves and water balance terms, some from Korzun (1978) and Baumgartner and Reichel (1975).

Problem is compounded by human interference and climate change, so there are pronounced changes over time, and the values for one time may not apply to another (very loose in literature).

Global hydrological cycle

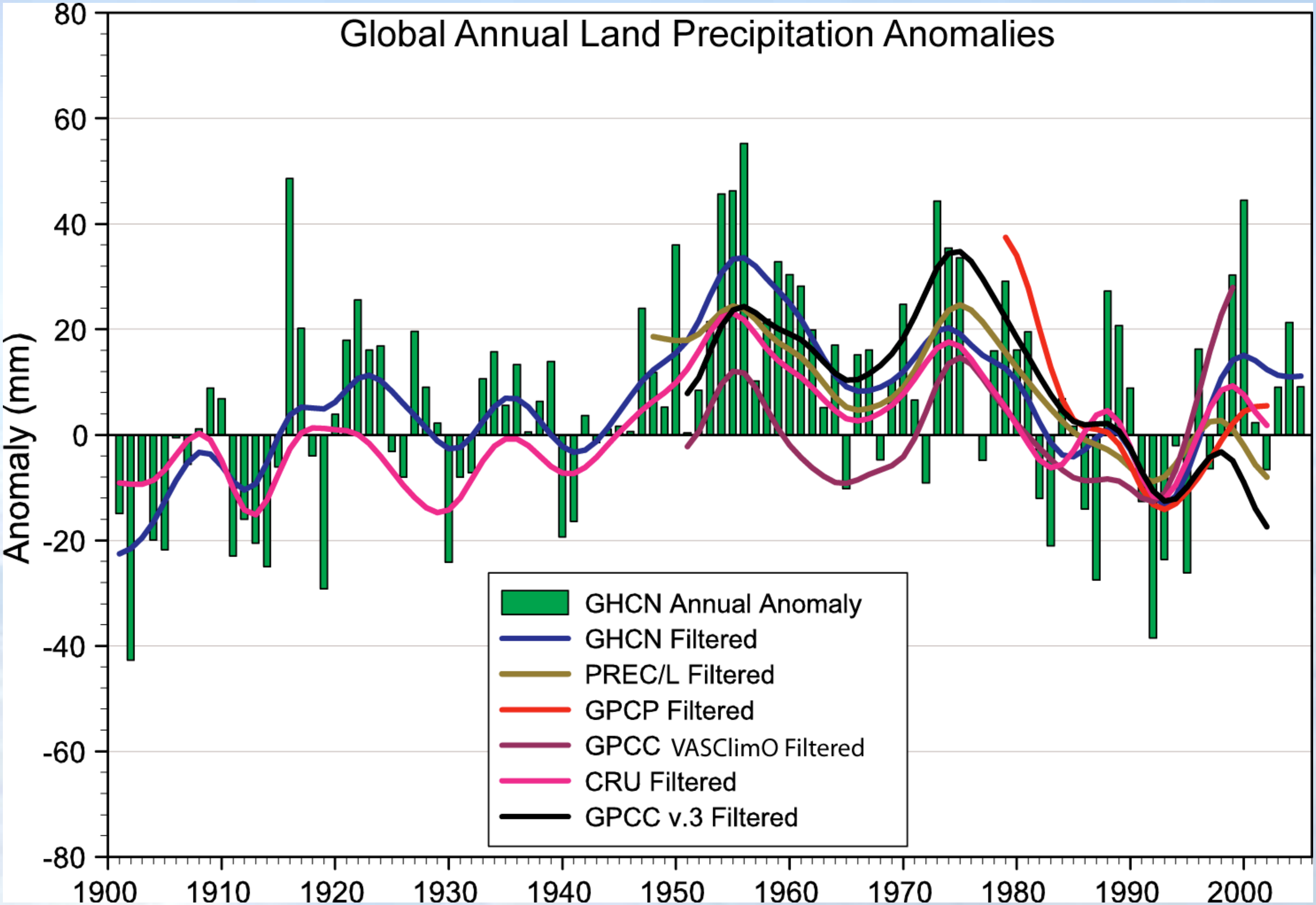
We use base period of 1988 to 2004:

This is when SSM/I data exist over oceans for precipitation.

Precipitation:

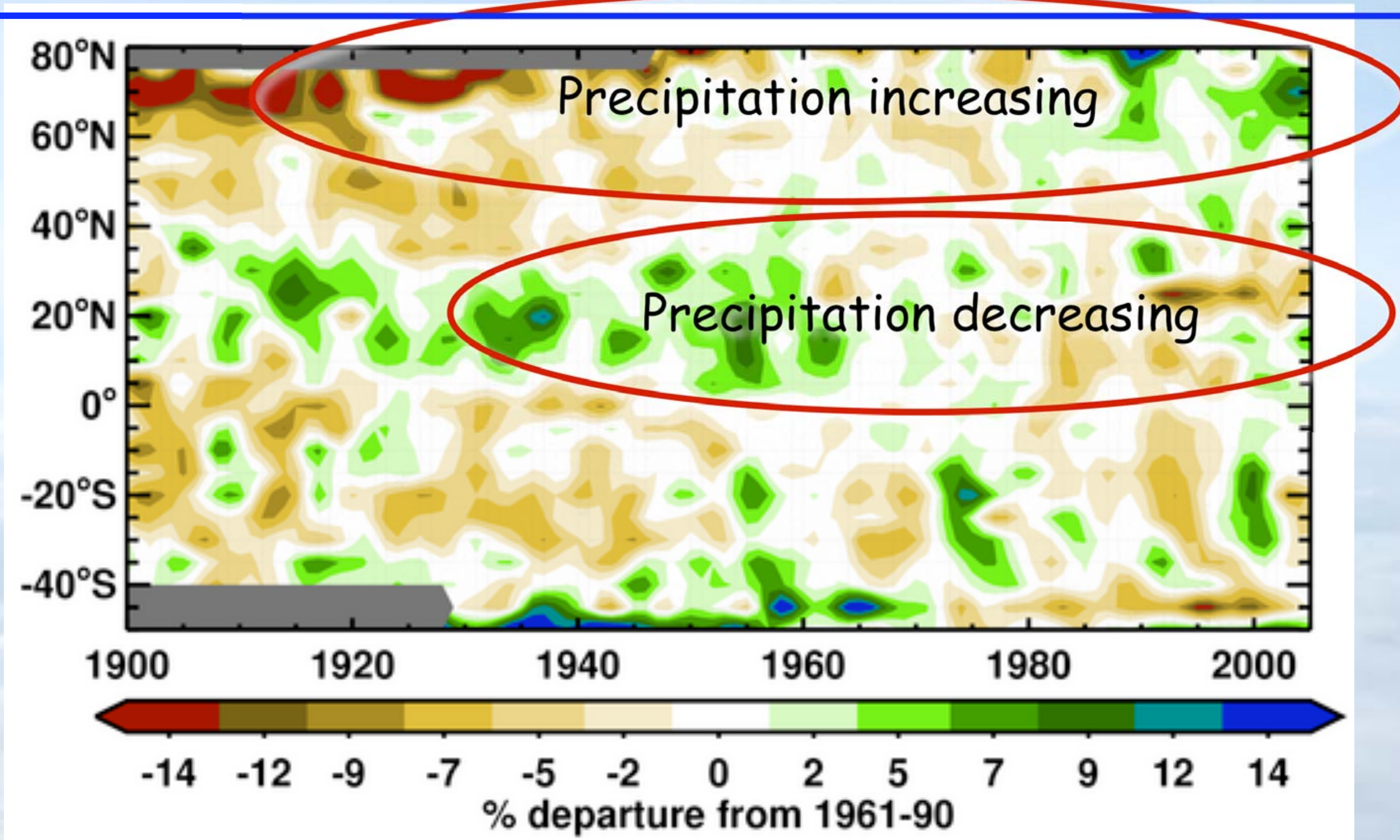
GPCP, CMAP over ocean

GPCP, CRU, Prec/L (GHCN, CAMS) over land



IPCC AR4 2007

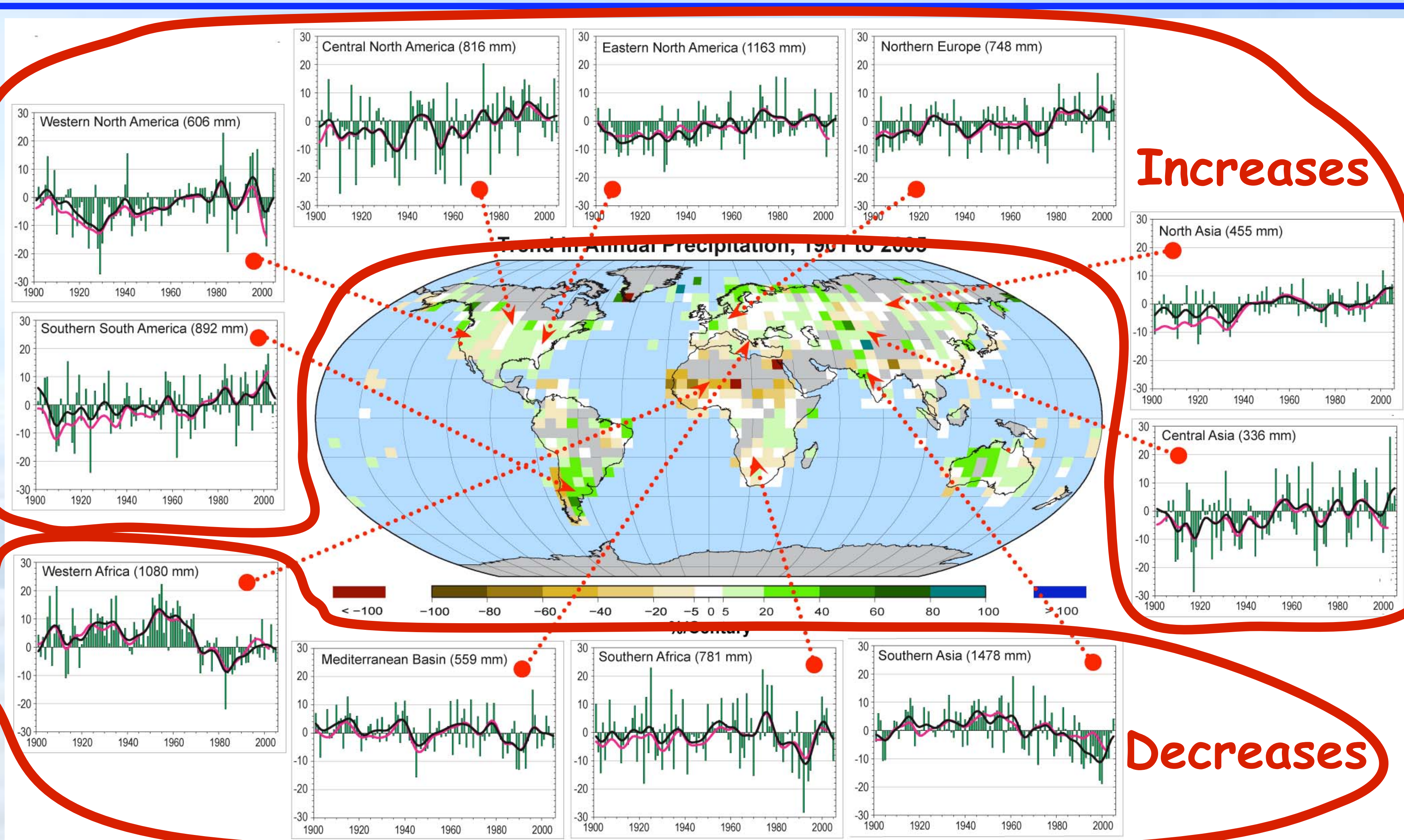
Land precipitation is changing



Latitude-time section of zonal average smoothed annual anomalies for precipitation (%) over land from 1900 to 2005

IPCC AR4 2007

Land precipitation is changing significantly over broad areas



Smoothed annual anomalies for precipitation (%) over land from 1900 to 2005; other regions are dominated by variability.

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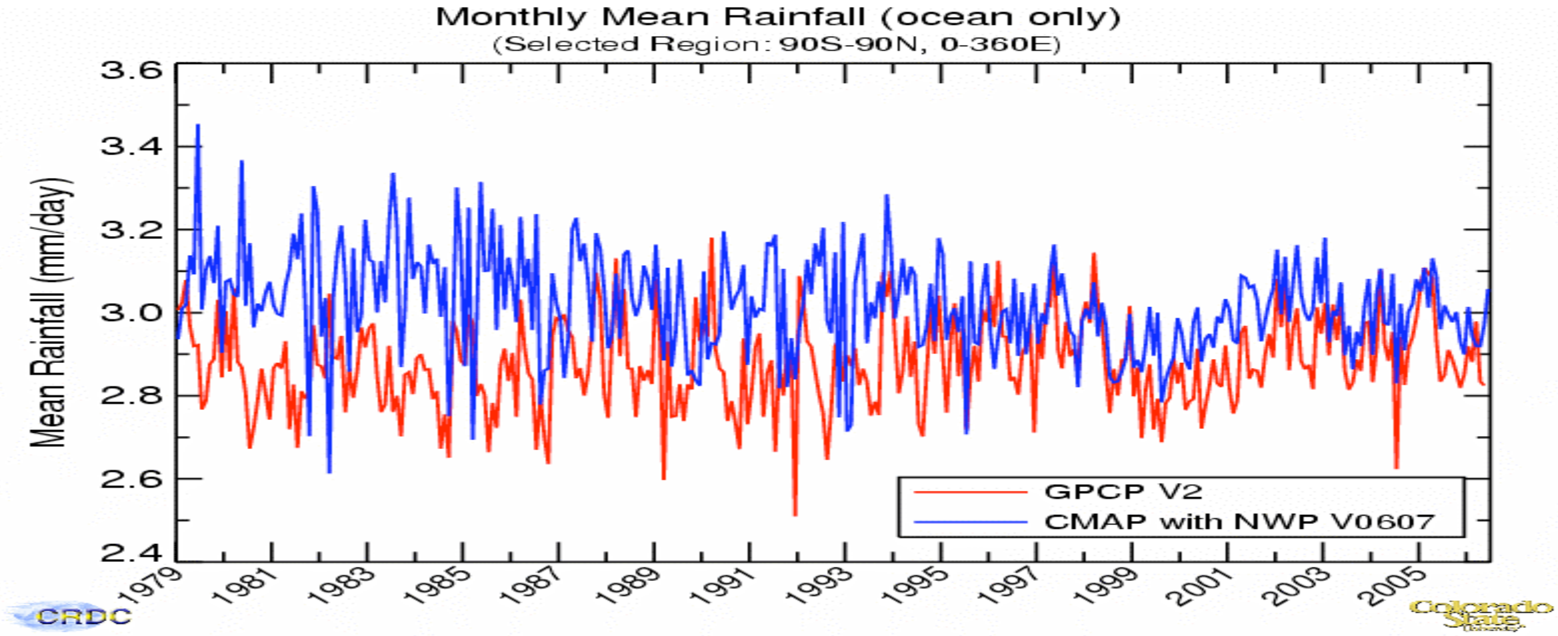
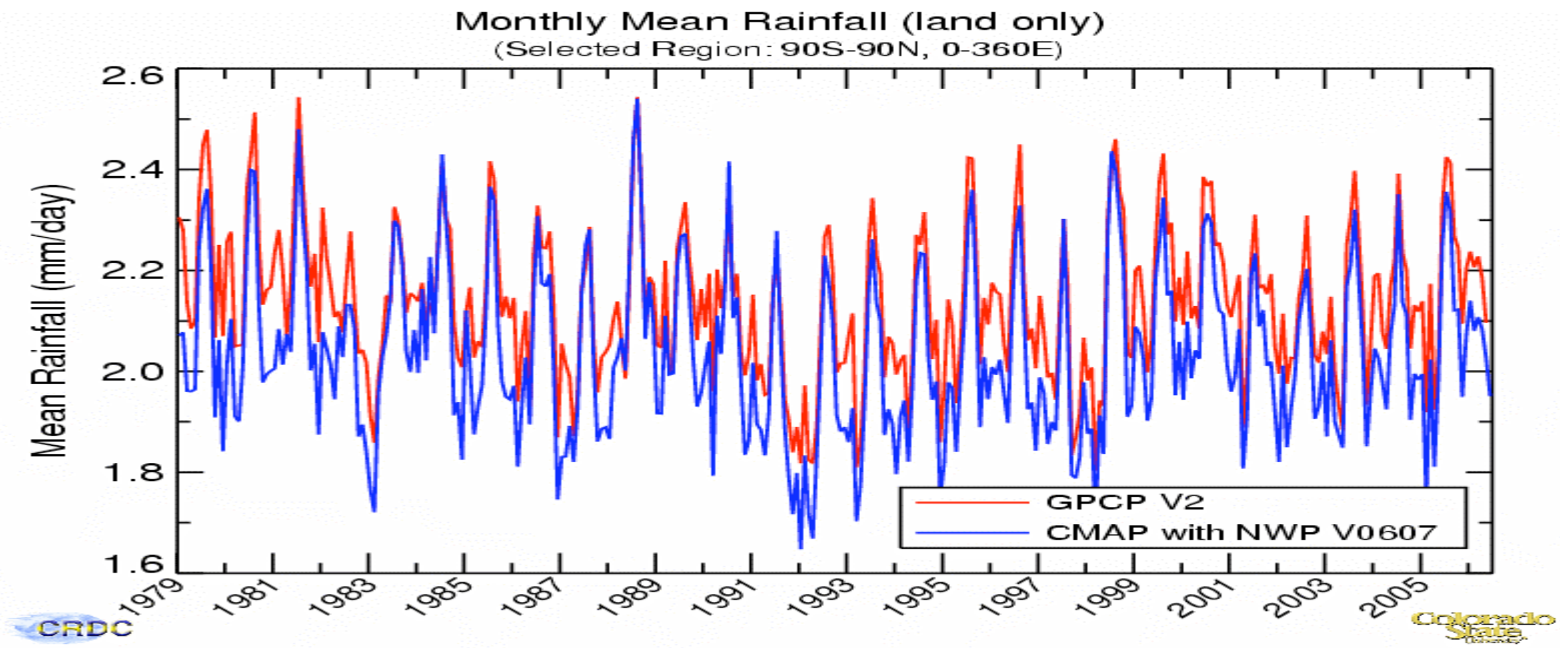
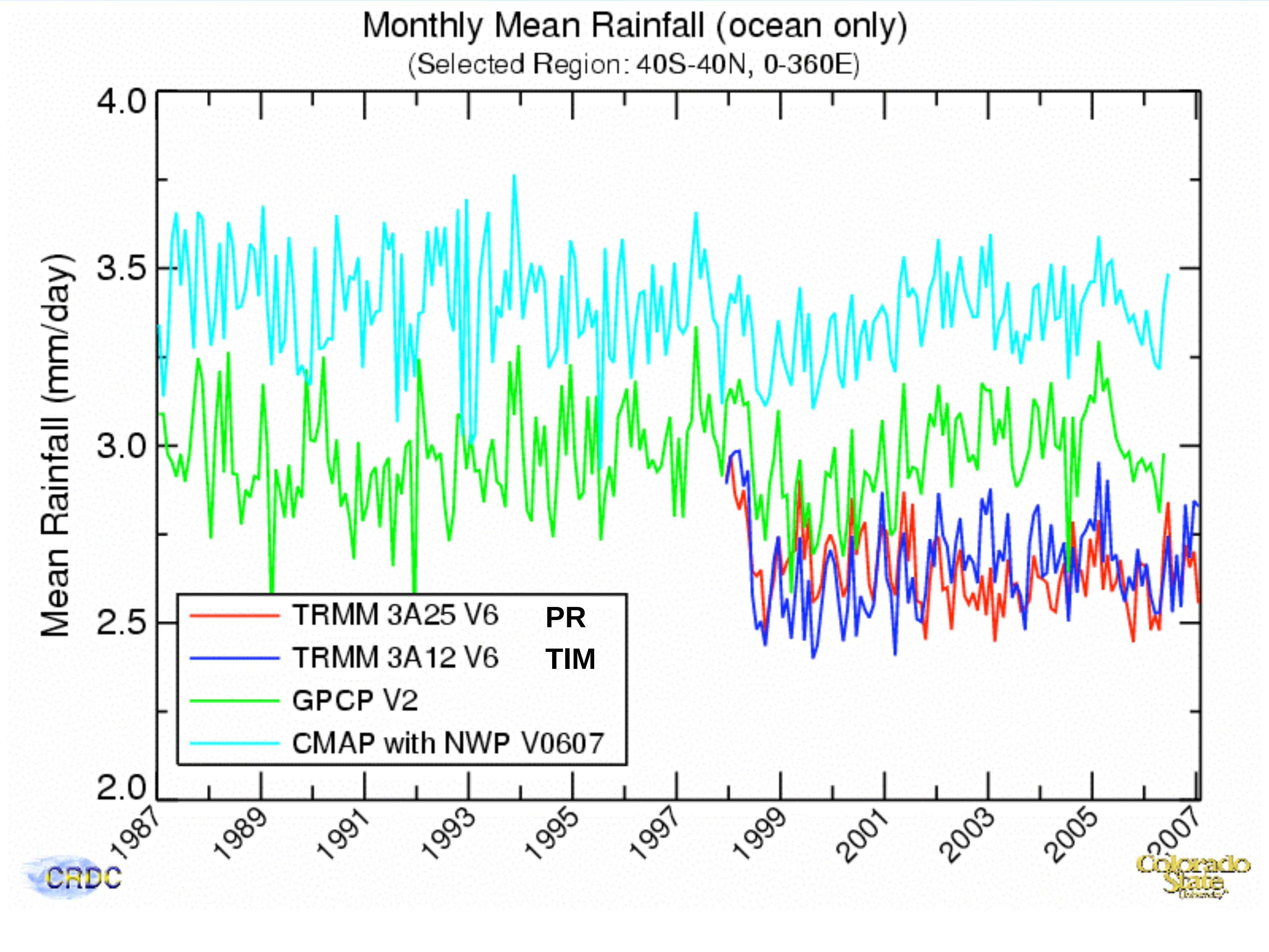
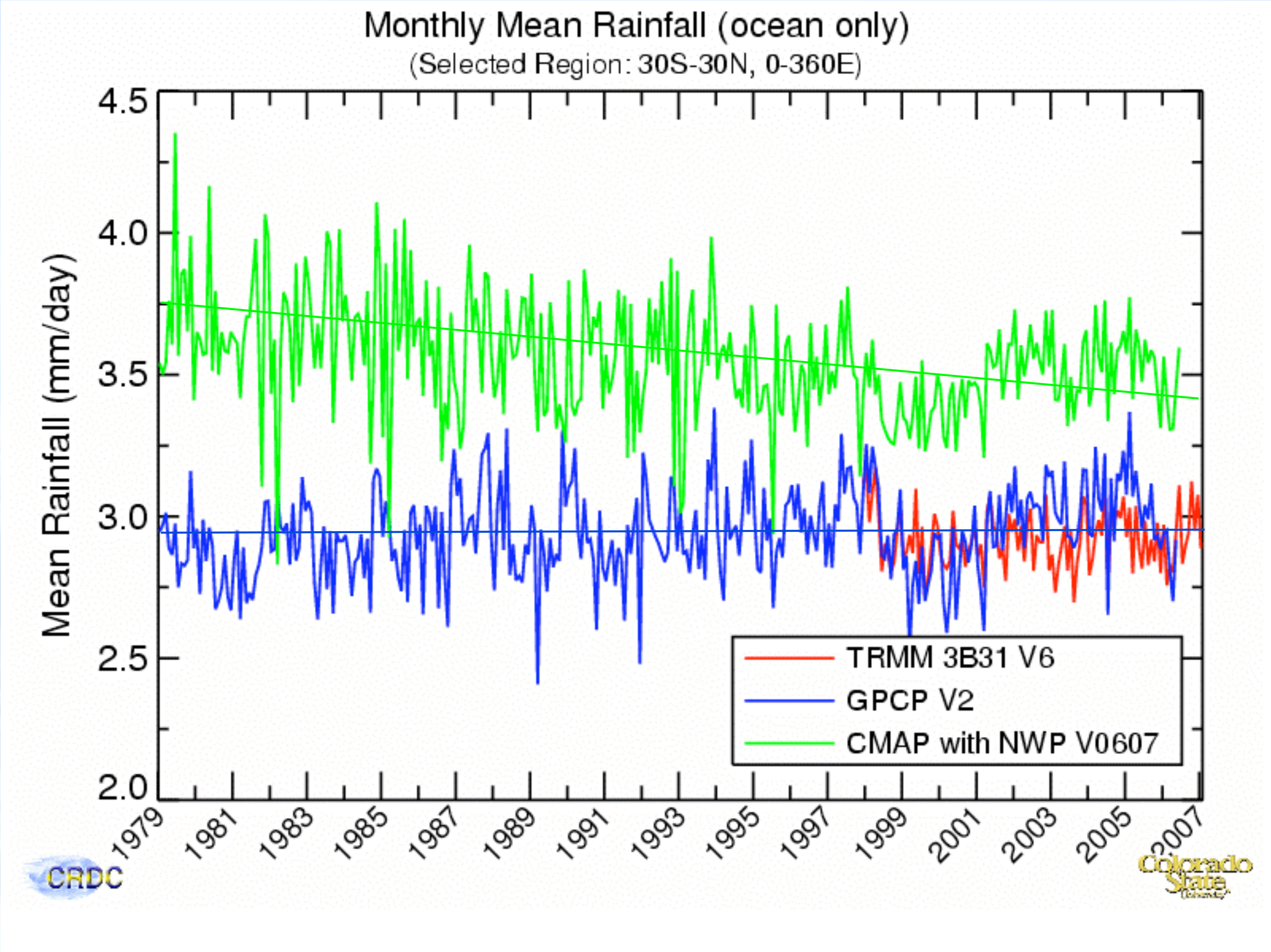


Monthly Mean Rainfall (ocean only)
(Selected Region: 90S-90N, 0-360E)
Mean Rainfall (mm/day)
3.6
3.4
3.2
3.0
2.8
2.6
2.4
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
GPCP V2
CMAP with NWP V0607
CRDC
Colorado State

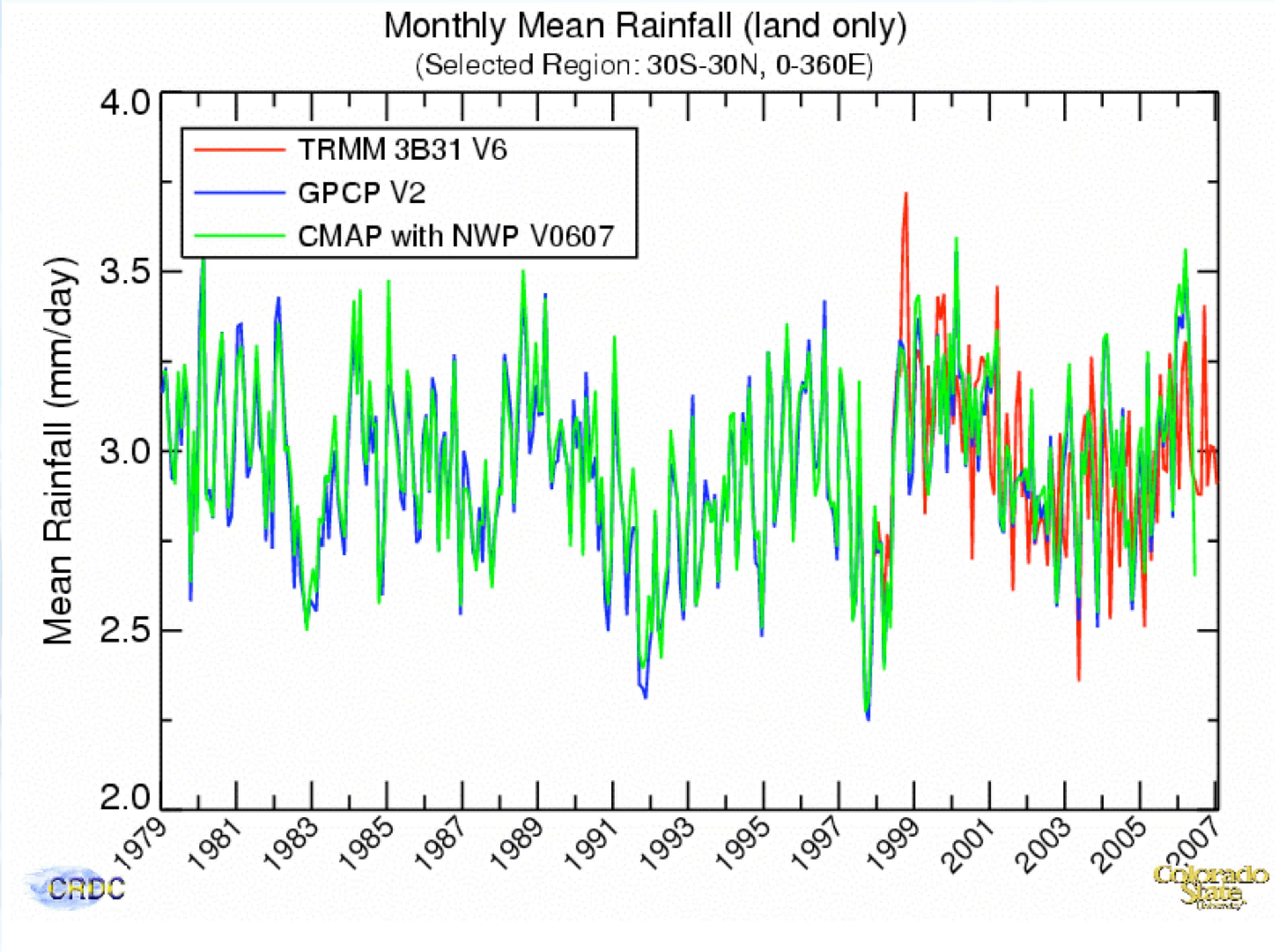


Monthly Mean Rainfall (land only)
(Selected Region: 90S-90N, 0-360E)
Mean Rainfall (mm/day)
2.6
2.4
2.2
2.0
1.8
1.6
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
GPCP V2
CMAP with NWP V0607
CRDC
Colorado State


Monthly Mean Rainfall (ocean only)
(Selected Region: 40S-40N, 0-360E)
Mean Rainfall (mm/day)
4.0
3.5
3.0
2.5
2.0
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
TRMM 3A25 V6
PR
TRMM 3A12 V6
TIM
GPCP V2
CMAP with NWP V0607
CRDC
Colorado State



Monthly Mean Rainfall (ocean only)
(Selected Region: 30S-30N, 0-360E)
Mean Rainfall (mm/day)
4.5
4.0
3.5
3.0
2.5
2.0
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
TRMM 3B31 V6
GPCP V2
CMAP with NWP V0607
CRDC
Colorado State



Monthly Mean Rainfall (land only)
(Selected Region: 30S-30N, 0-360E)
TRMM 3B31 V6
GPCP V2
CMAP with NWP V0607
Mean Rainfall (mm/day)
4.0
3.5
3.0
2.5
2.0
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
CRDC
Colorado State

Precipitation units: 10^3 km^3

Global	486.9±2.9	2 sigma temporal sampling	
Ocean:	max: October	381.2	
	min: June	365.0	
	Annual	**372.8±2.7**	

Chahine 92	398	
Peixoto & Oort 92	324	(way too low)
Shiklomanov 93	458	(way too high)
Oki 99	391	(CMAP, short period)

Precipitation: 10^3 km^3

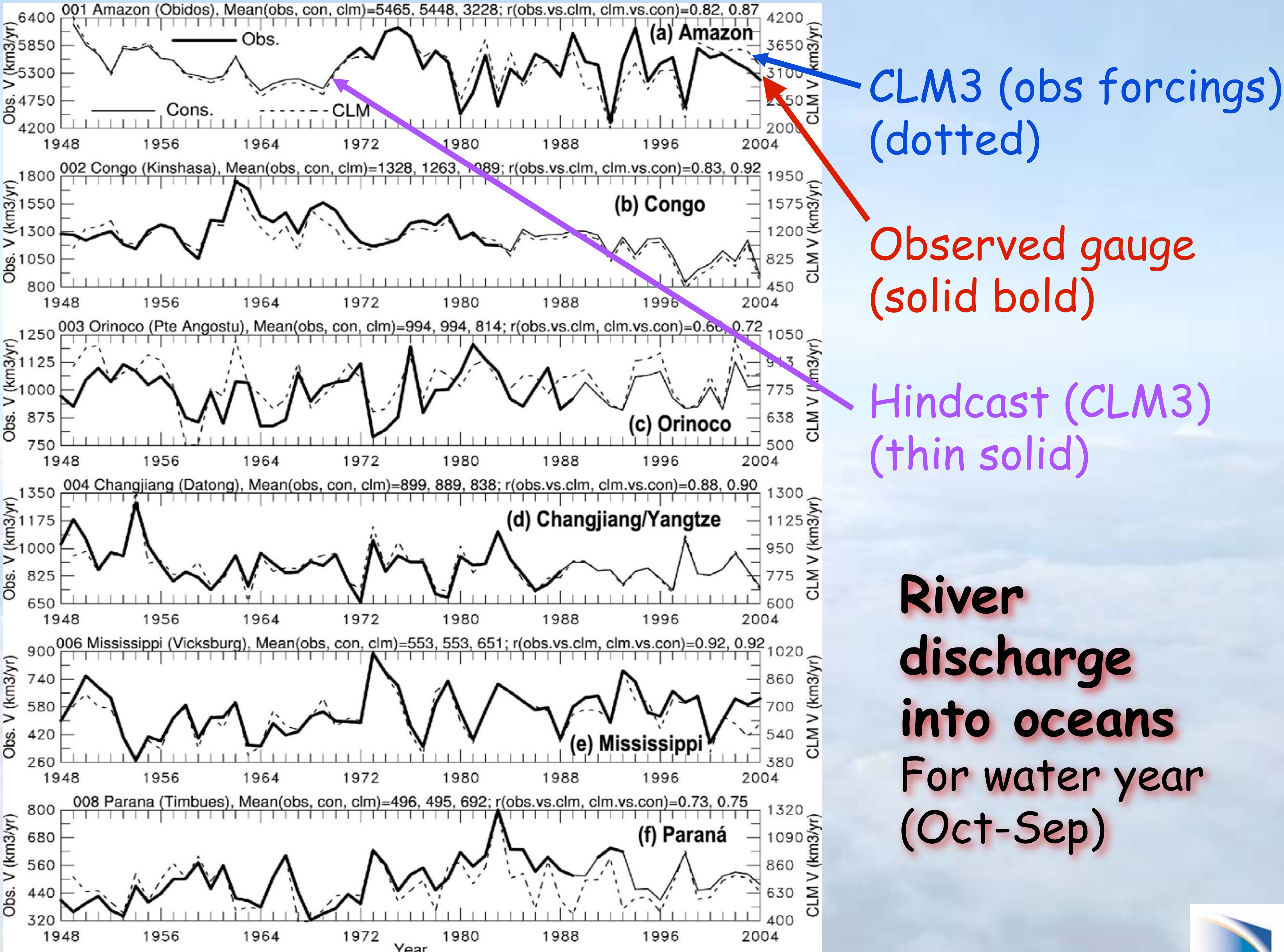
Global 486.9±2.9 2 sigma

Land:	GPCP*: max July	127.9
	min Feb	104.7
	Annual	**112.6±1.4**
	PREC/L	111.2 ±1.2
	CRU (no Antarctica)	109.5±1.3
	Oki 1999	115
	Oki and Kanae 2006	111
	Chahine 1992	107
	Shiklomanov 1993	110
	Peixoto and Oort 1992	99

Antarctica accounts for about 1% diffs. Reasonably close (2%), given different time periods.

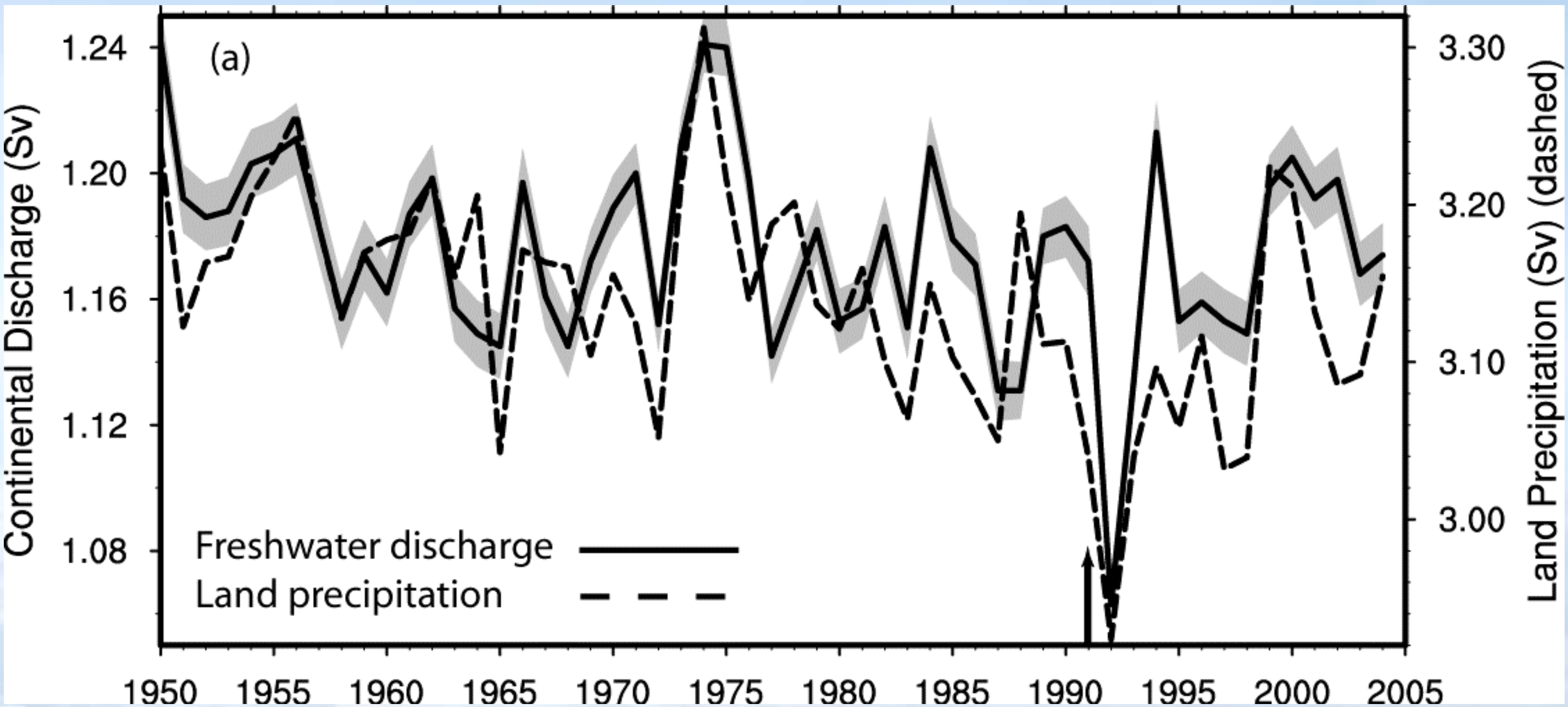
low

* Has adjustment for undercatch

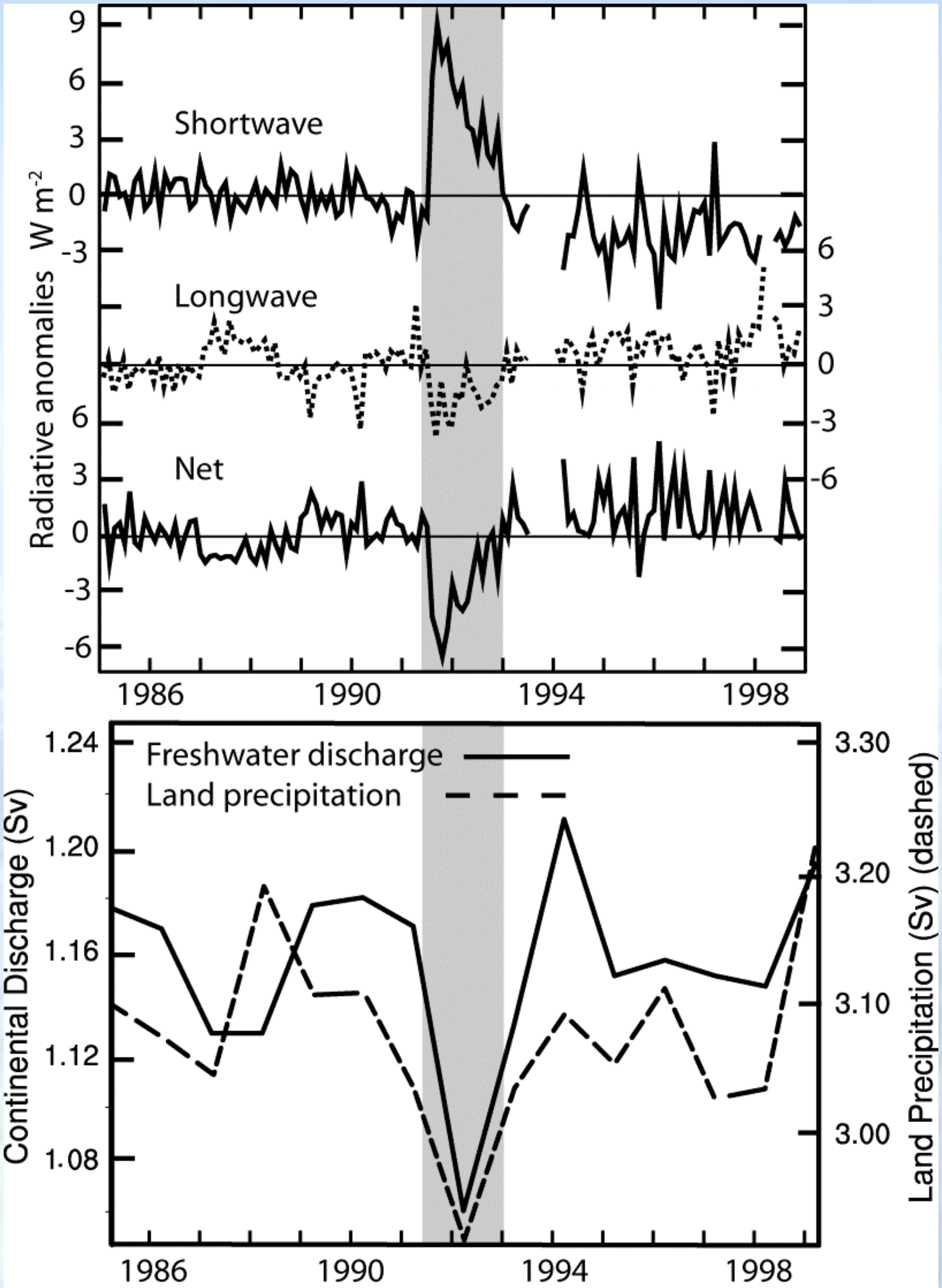


River discharge into oceans

For water year (Oct-Sep)



Estimated water year (1 Oct-30 Sep) **land precipitation** and river **discharge** into global oceans based on hindcast from output from CLM3 driven by observed forcings calibrated by observed discharge.



Mount Pinatubo in June 1991 had a pronounced effect on land precipitation and runoff. Ocean precipitation was also slightly below normal, and the global values are lowest on record.

Other notes:

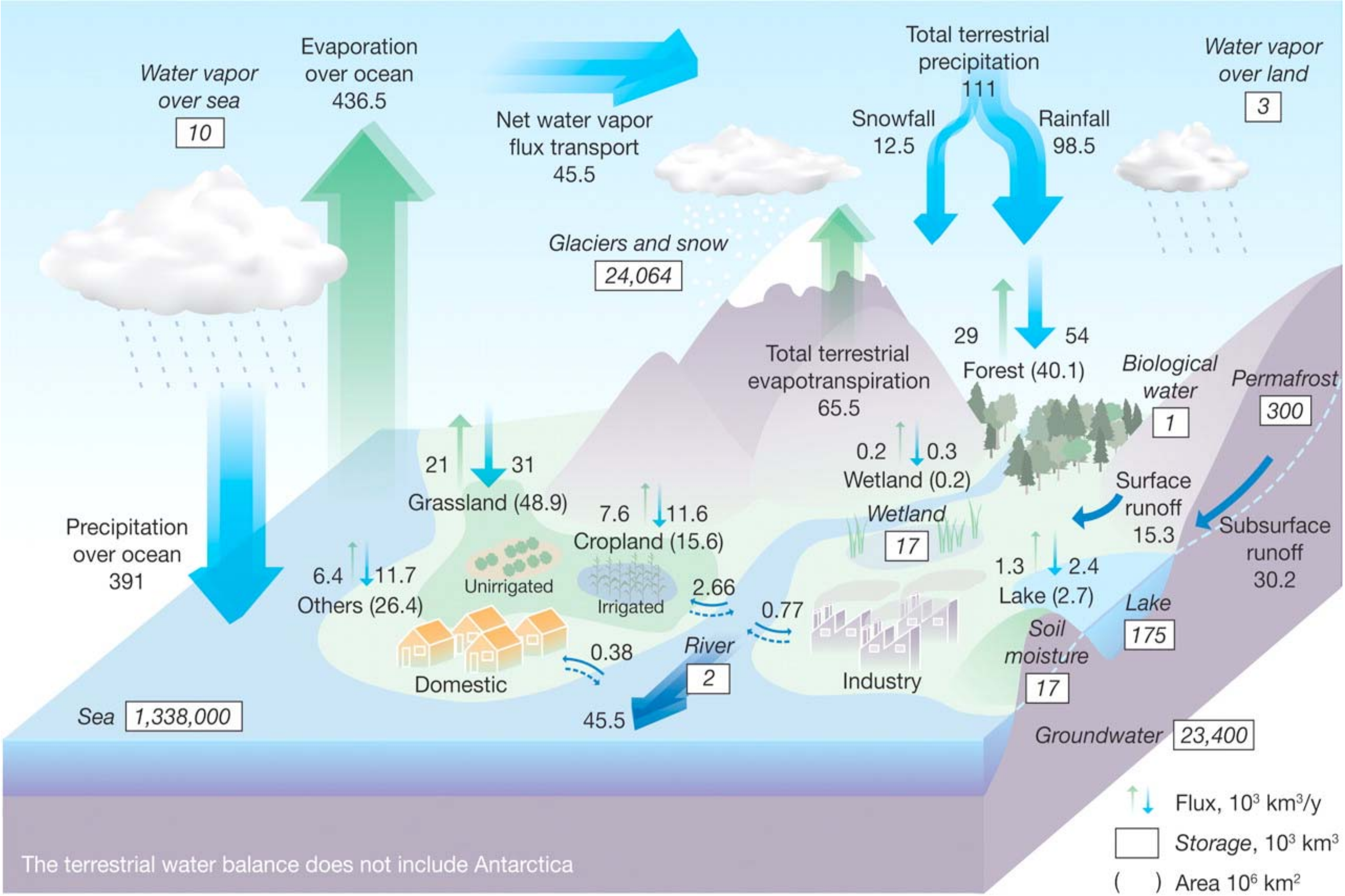
Ice volume is quite uncertain: The height of Antarctica has changed by over 1 km in some places in last 15 years. A 0.917 factor is used to convert ice to water.

Ocean volume is computed using latest 5′ NGDC data base. Usually overestimated in the past.

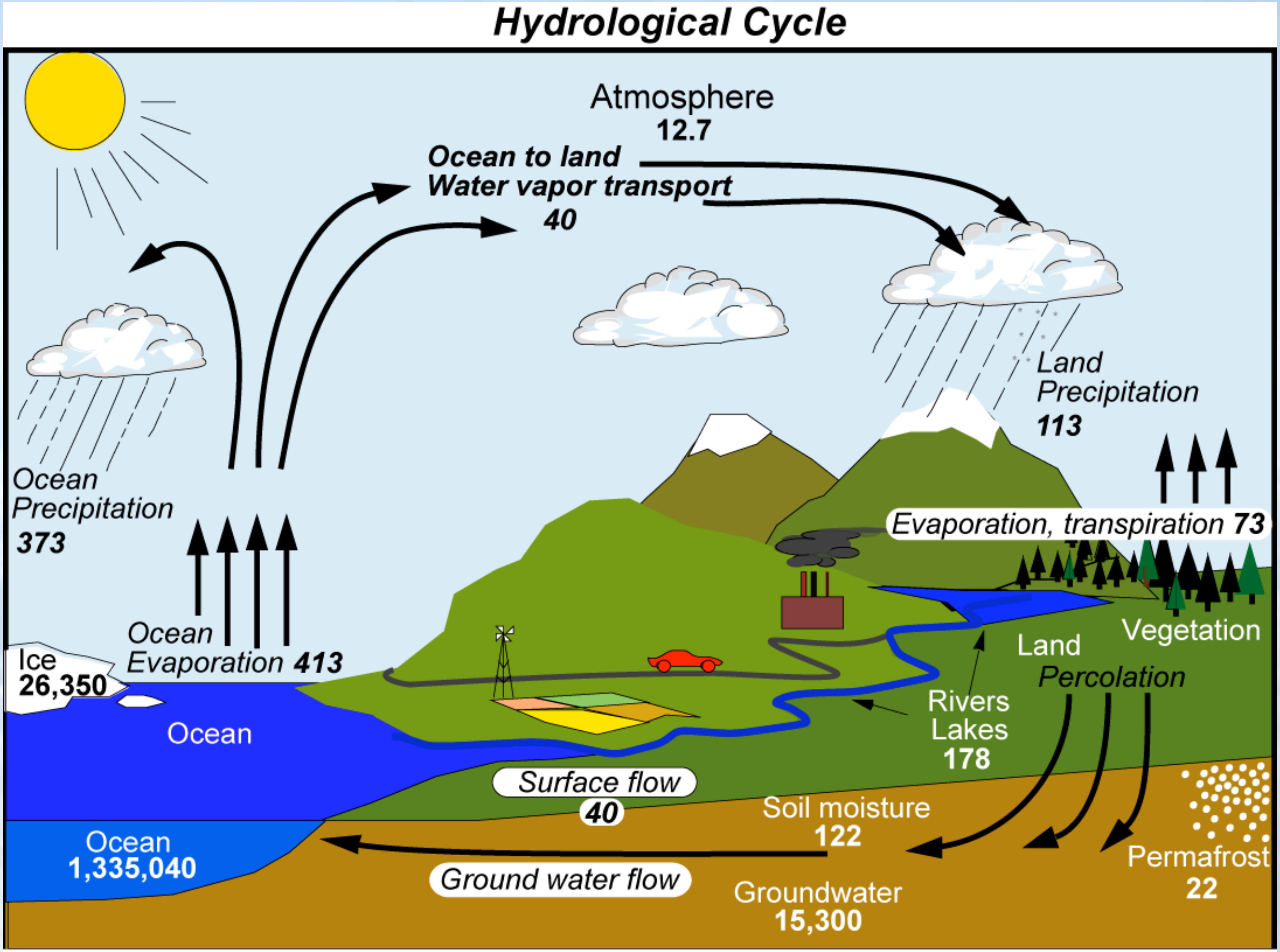
Permafrost is very uncertain. 24% of land surface. Zhang et al 1999: 11 to 36×10^3 km^3 for "excess ground ice" but pore ground ice is 190 to 290 $\times 10^3$ km^3 or more.

River discharge is from Dai and Trenberth (2002) with an extra allowance for Antarctica. In CLM we find 40.4 $\times 10^3$ (1979-2000) but 41.8 $\times 10^3$ for 1948 to 2004.

Evaporation is the residual of P and R.



Oki and Kanae, Science, 2006

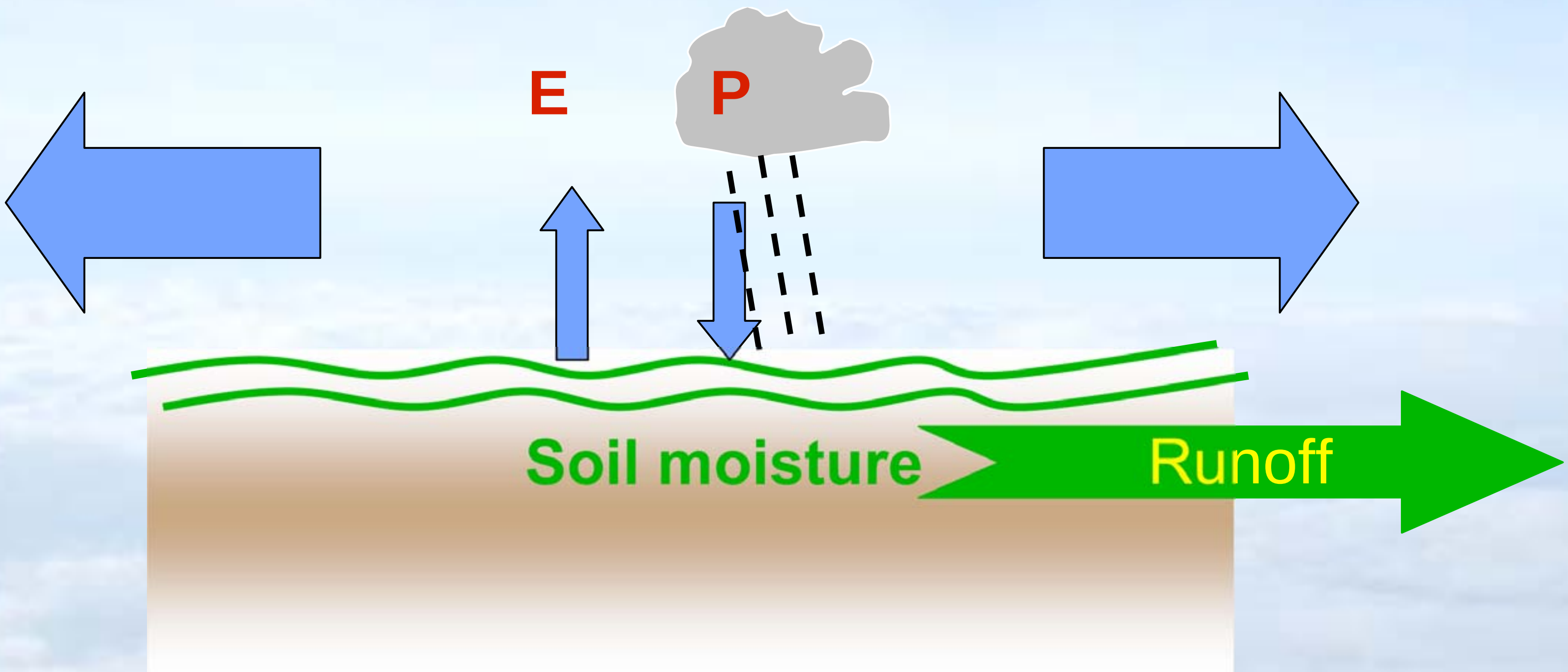


Units: Thousand cubic km for storage, and *thousand cubic km/yr* for exchanges

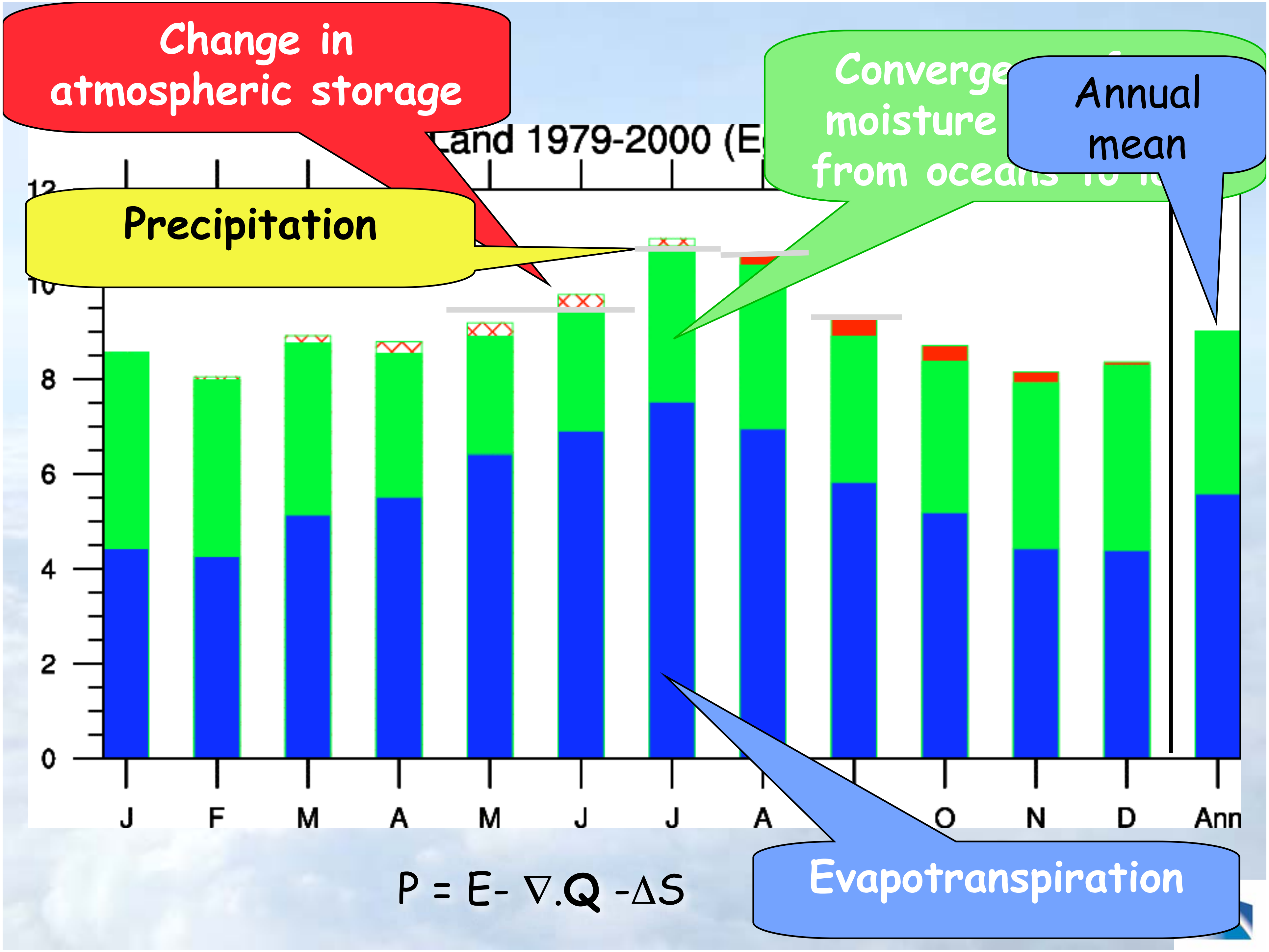
Trenberth et al 2007 in press *J Hydromet*

Diagnostics:

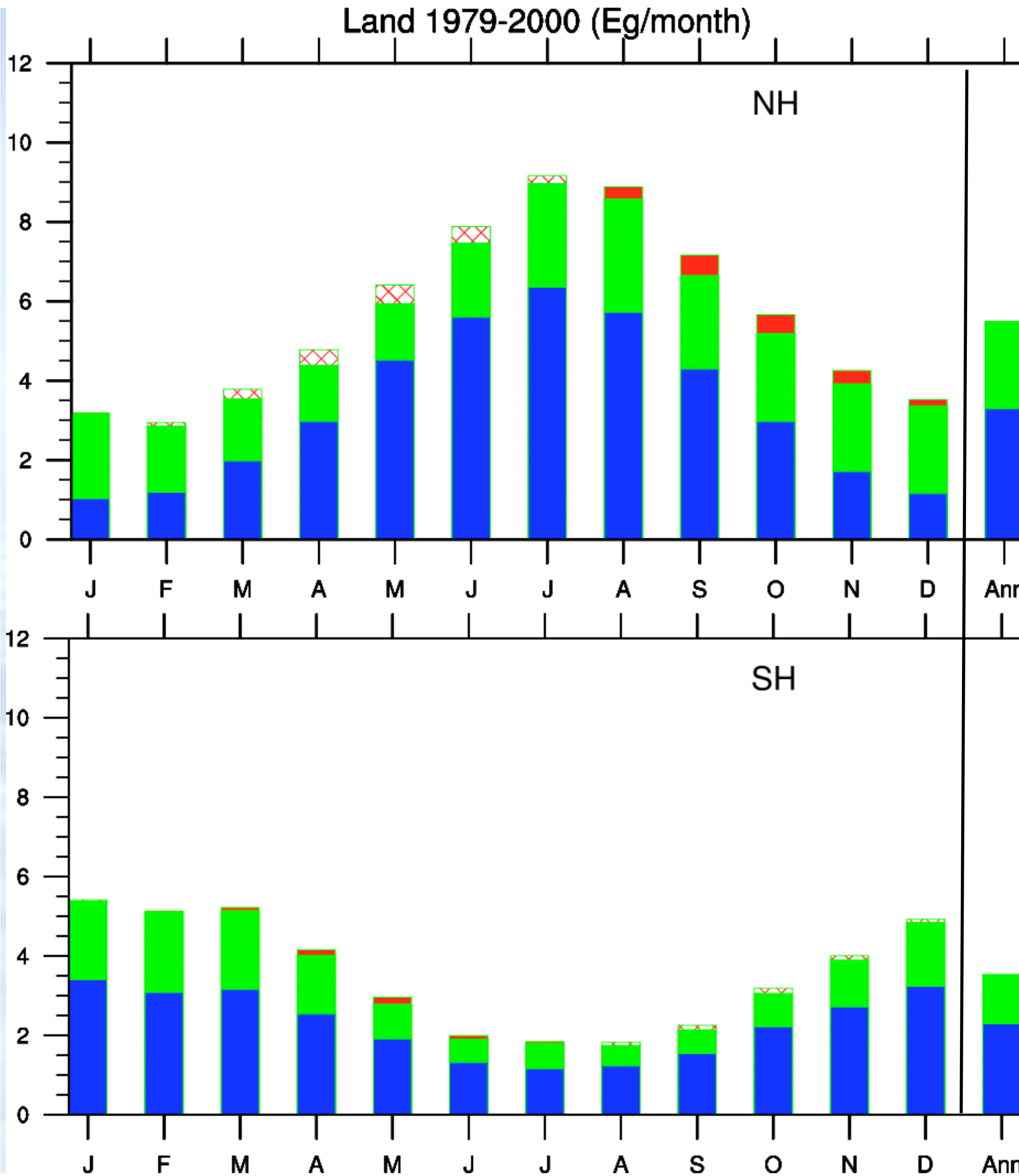
Divergence of atmospheric moisture is balanced by E-P and change in atmospheric storage



Divergence of surface moisture
= runoff
is balanced by E-P
plus change in soil moisture storage



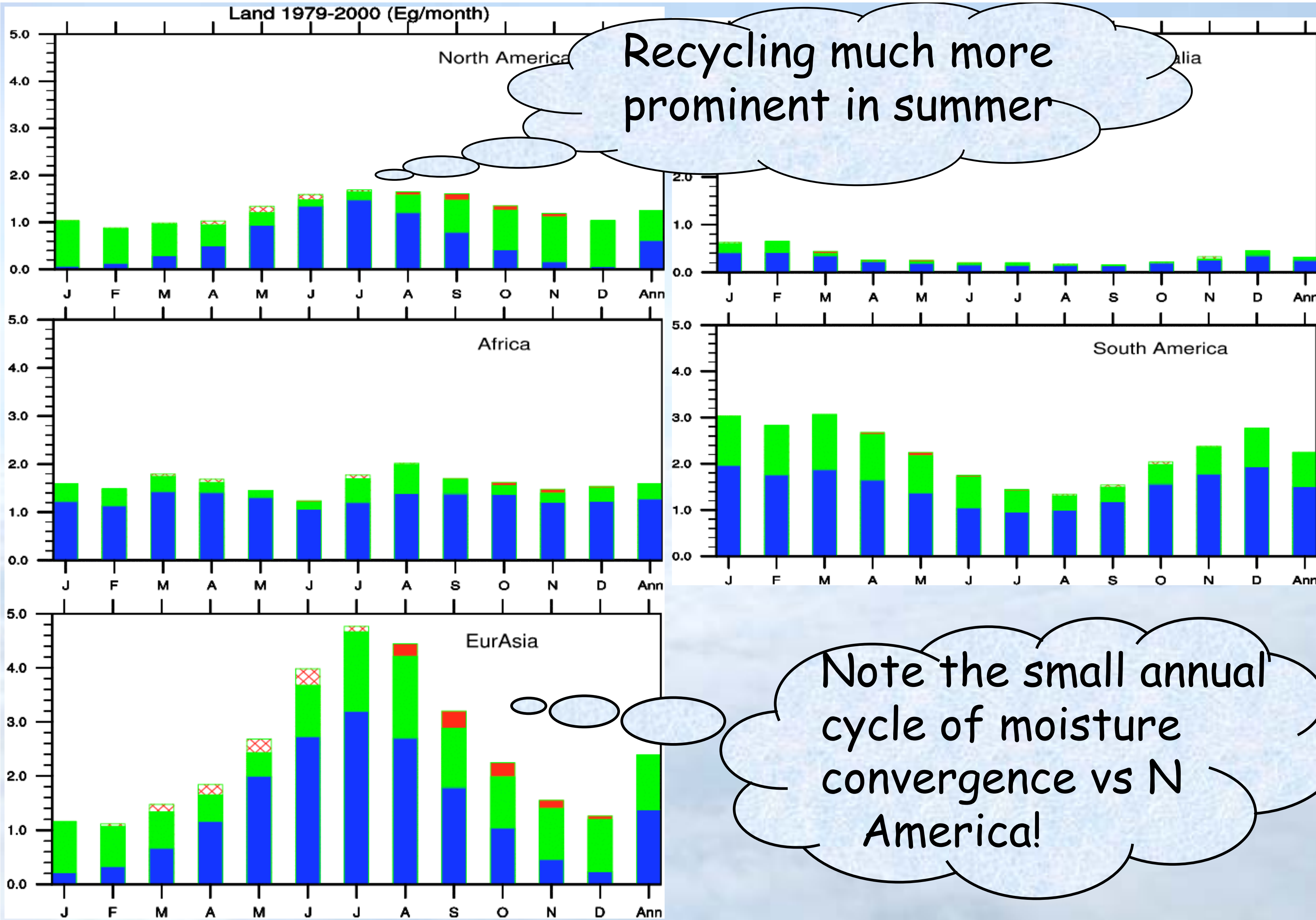
$$P = E - \nabla.\mathbf{Q} - \Delta S$$



LAND

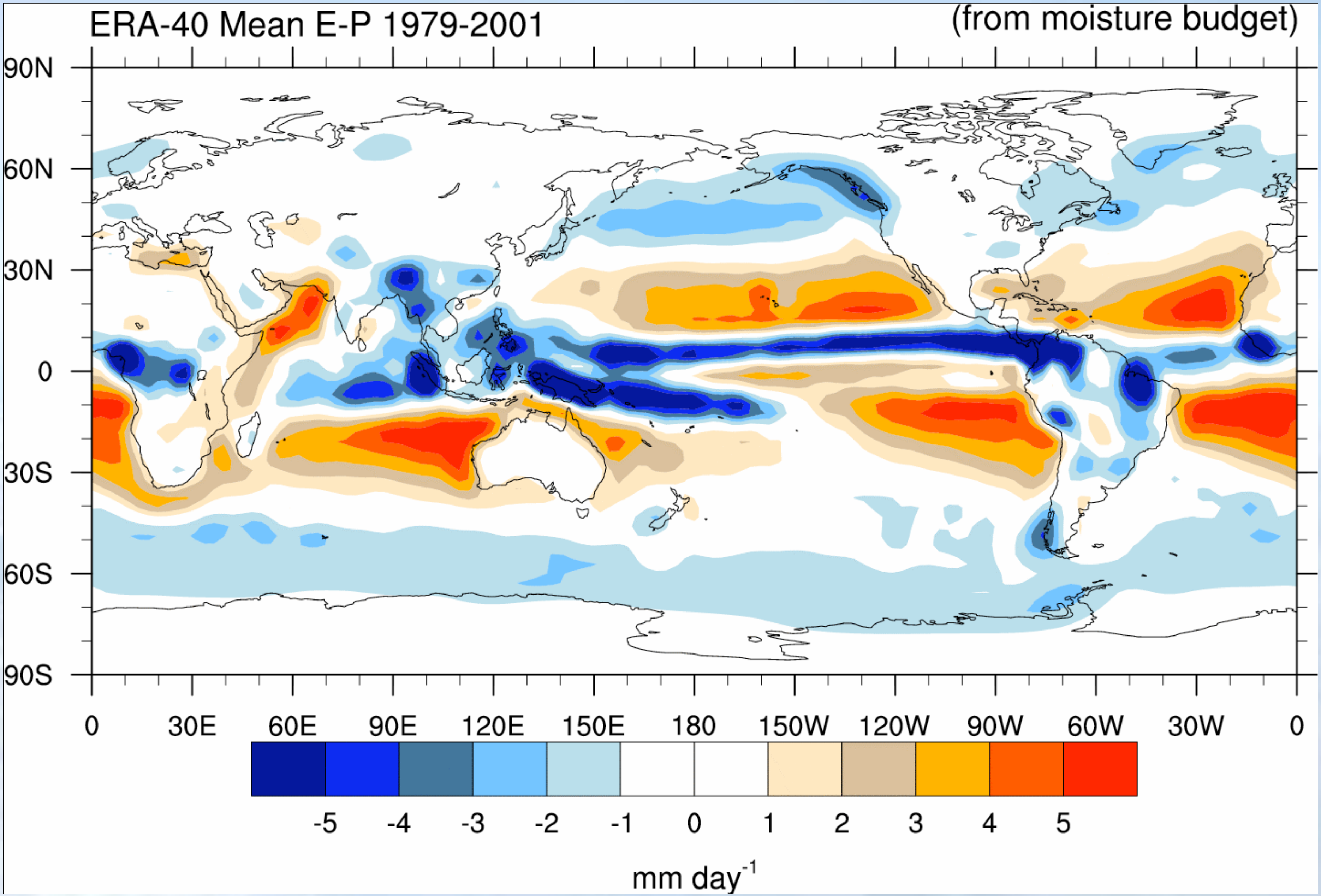
NH

SH

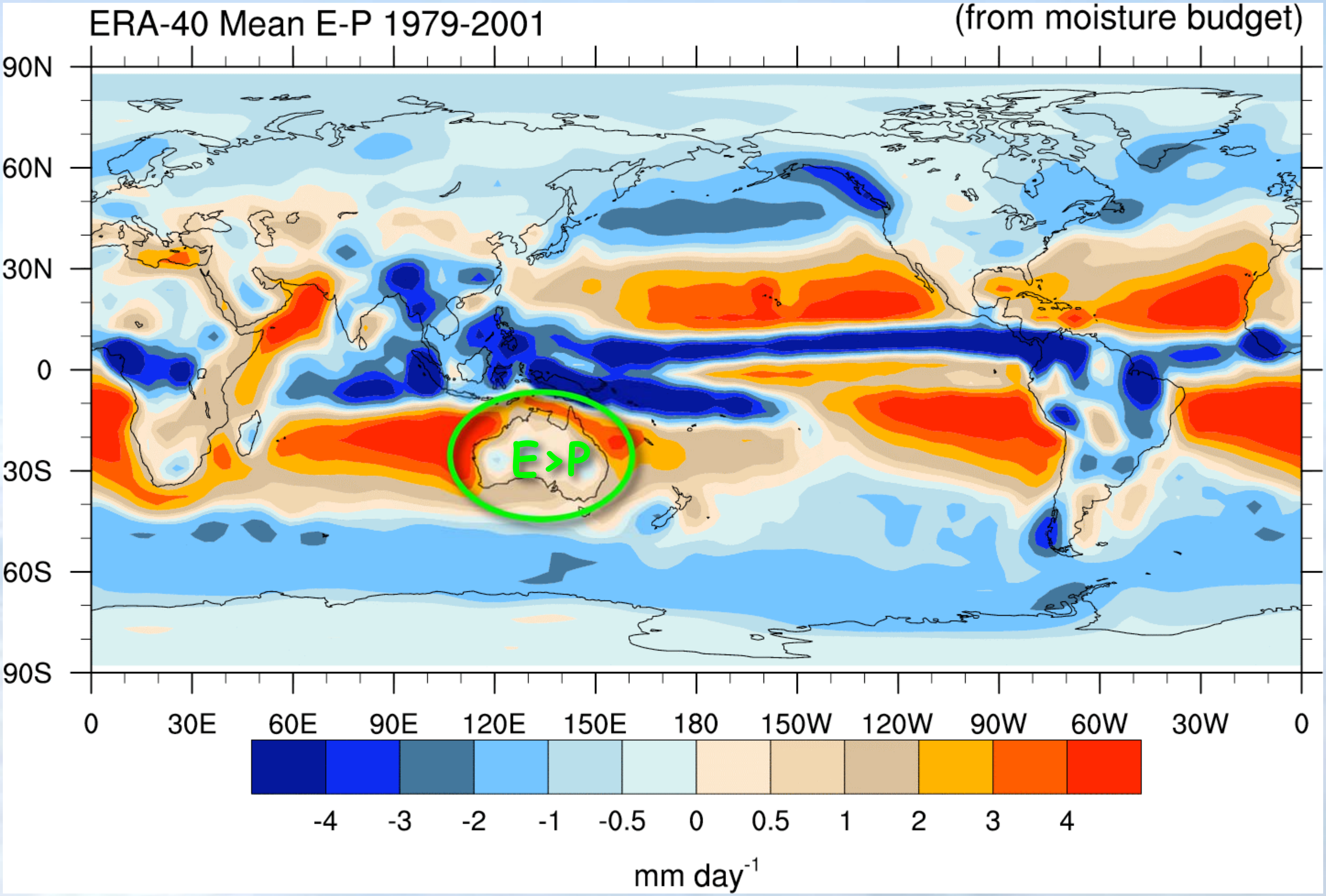


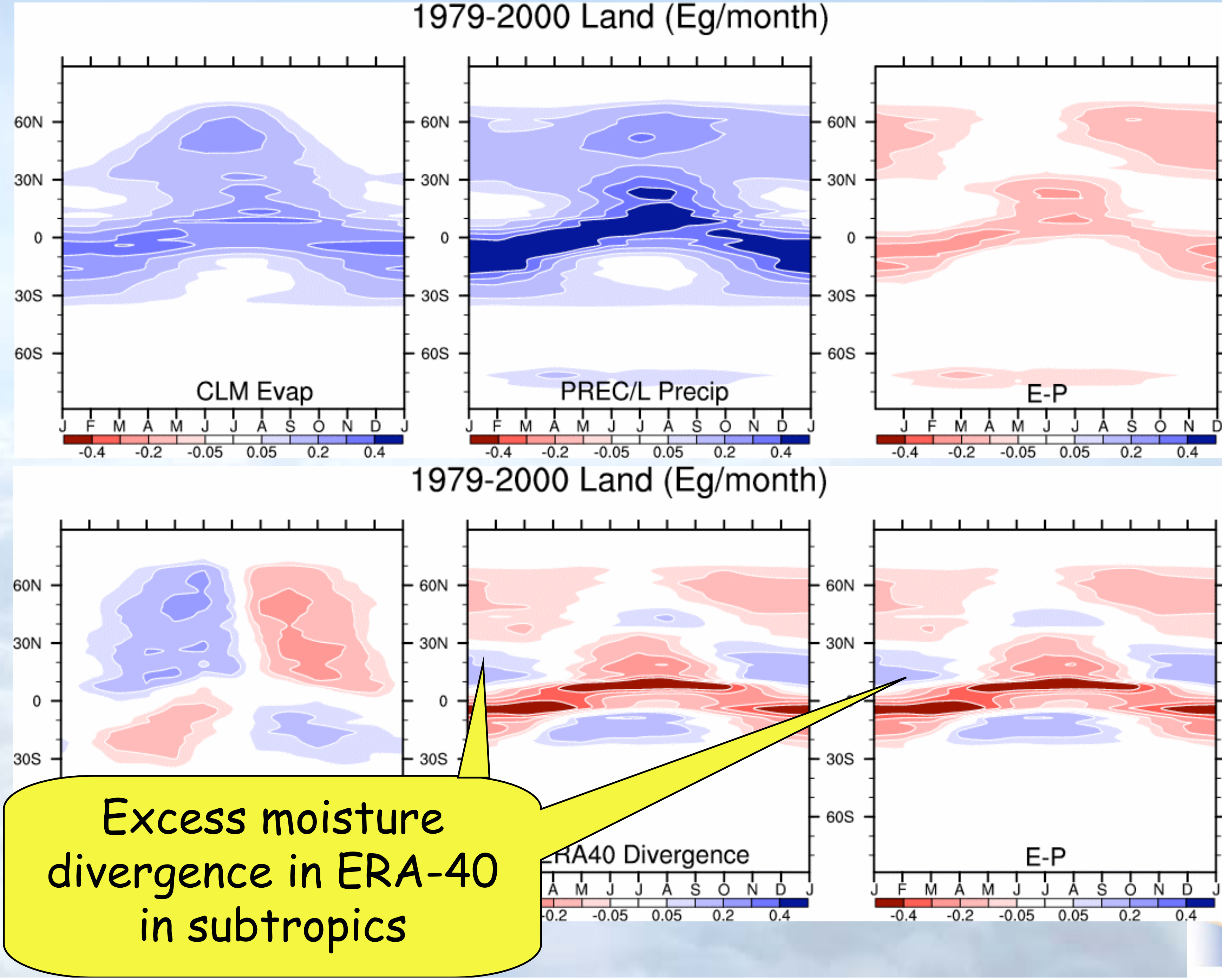
Recycling much more prominent in summer

Note the small annual cycle of moisture convergence vs N America!



ERA-40 Mean E-P 1979-2001
(from moisture budget)
90N
60N
30N
0
30S
60S
90S
0
30E
60E
90E
120E
150E
180
150W
120W
90W
60W
30W
0
-5
-4
-3
-2
-1
0
1
2
3
4
5
mm day⁻¹


ERA-40 Mean E-P 1979-2001
(from moisture budget)
90N
60N
30N
0
30S
60S
90S
0
30E
60E
90E
120E
150E
180
150W
120W
90W
60W
30W
0
E>P
-4
-3
-2
-1
-0.5
0
0.5
1
2
3
4
mm day-1



1979-2000 Land (Eg/month)
CLM Evap
PREC/L Precip
E-P
1979-2000 Land (Eg/month)
ERA40 Divergence
E-P
Excess moisture divergence in ERA-40 in subtropics

Some Recommendations

- There is a compelling need to **reprocess** satellite-based climate datasets for precipitation, cloud, water vapor, runoff, hurricanes, sea ice, soil moisture, etc.
- There is a great need to do a better job in **reanalyses** of all data wrt the hydrological variables
- Improved modeling of hydrological variables: diurnal cycle; frequency, intensity, duration, amount and type of precipitation; trends
- In situ data are declining, yet we need **hourly** data to do analyses of precipitation (incl. rates, extremes), moisture
  - Recording gauges, radar, satellite; gps
- Synthesis and integration of the hydrological variables so they are processed and analyzed together and not independently: likely in a model framework.
- Clarification of human effects: withdrawal, irrigation etc
- Complete **budgets**.